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THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

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A SIMPLE METHOD OF DETERMINING THE TIME

BY WILLIAM H. PICKERING

WHEN it is only required to know the time within a second or two the following method of obtaining it, without instrumental aid, will be found a very satisfactory one. For certain classes of astronomical work, notably photography, and for many kinds of visual observations, particularly on the planets and brighter stars, this accuracy is all that is needed. When no other work is done at a station, so that the time observations are merely a means to an end, and not the end itself, or in the case of any amateur astronomer who is located far from a telegraph station, and wishes simply to know approximately what time it is, the following method of observation is recommended.

The object in my own case was to waste no time at night on time observations, which might better be applied to work that was worth while. If daylight observations were to be employed, the object must necessarily be the sun.

It was suggested to me by Professor W. P. Gerrish that by using proper precautions, the time of transit of the shadow of a rod across a line ruled on a screen could be determined within a few

seconds. This was found to be the case, and the question was then simply to find the best method of constructing a sun-dial.

A half-inch steel bar, eighteen inches in length, was supported horizontally upon Ys, which were capable of adjustment upon a cast iron base. This was set on the top of a concrete column six feet in height having a cement surface surrounding it. One end of the bar projected about six inches beyond the column. This could all, of course, be much simplified by the amateur who would be satisfied with somewhat less accuracy. By means of two plumb lines sighted on Polaris at upper culmination, it was possible to lay off a meridian with sufficient accuracy, and to mark it by means of screws driven into the flat cement surface at the base of the column. A pencil line was ruled between the slots of the screws. The amateur need only choose a time for sighting on Polaris when δ Cassiopeiæ or ζ Ursæ Majoris appears directly above or below it. Then by sighting from behind one plumb line upon the other the required meridian will be obtained.

A simple transit of the shadow cast by this rod across the meridian line gives the time of Apparent Noon, but better results are obtained by taking a piece of red paper pasted on a card or envelop, and dividing off its two longer sides into intervals of a quarter of an inch. The middle division is continued straight across the card. The divisions are numbered successively, and the middle division may then be placed so many quarters of an inch on either side of the meridian mark. By sliding the card along, we may in this manner obtain several transits of the shadow across this middle division, instead of only one, as if we used the meridian line directly. By taking five transits symmetrically distributed with regard to the meridian mark, it is found that the average deviation of a single transit is usually in the neighborhood of two seconds. The probable error of the mean would, therefore, be about one second, which is quite as accurate a result as could be obtained with a sextant, and entirely avoids the lengthy and troublesome computation necessary with that instrument. The red paper was selected as being less trying

to the eyes than white, but shaded spectacles are also employed for further protection.

In the OBSERVER'S HANDBOOK, pp. 6 and 7, will be found a column headed "Equation of Time," by which we may convert our Apparent Time directly to Mean Time. A further constant correction must be made for the longitude of the station, to convert to Standard Time, and that is the only computation needed to obtain our results.

While a horizontal bar has been employed in our latitude, + 18°, it is probable that beyond + 45° a vertical rod at a less elevation would give better results, at least, in the winter time. Another method would be to employ two walls lying east and west and situated about six feet apart. The sun shining through a small hole in the southern wall would cast its image on the northern one, and a vertical line ruled on this in the proper place as determined by Polaris would serve to mark the meridian passing through the hole. In the summer time the image would lie on the ground between the two walls. A modification of this plan has been used by Mr. Maxwell Hall, of this island. It has the advantage over the shadow method, that the latter gives trouble when there are thin clouds passing over the face of the sun, the shadow shifting so that it is impossible to obtain a satisfactory result.

By any of these methods the systematic errors are the ones chiefly to be feared. In many places the chief of these would lie in the uncertainty as to the longitude of the station, and this error would affect the most refined instrumental observations equally with those above described. An error of one mile in the assumed longitude would introduce an error of about four seconds in our result, and the further north we went the greater would this error become.

HARVARD ASTRONOMICAL STATION.
MANDEVILLE, JAMAICA, W.I.

TWO OLD UNSOLVED PROBLEMS OF ASTRONOMY

By Arthur B. Turner

THE recent appearance of a valuable memoir* by Professor Eric Doolittle brings again, forcibly to mind the fact that the Newtonian theory of gravitation is not in complete harmony with all astronomical observations. From the vague ideas of Ptolemy of a universal pervading force, through the observations of the skilful Tycho Brahe, through the empirical laws laboriously evolved by Kepler from these, we come to the transcendent genius of Newton who showed that a force of attraction varying with the product of the masses of two bodies and inversely as the square of the distance between their centres was sufficient to explain the motion of the planets, their satellites and even the motion of comets. Since Newton, many other minds — like those of Lagrange and Laplace — have woven a wonderful fabric based upon this law of universal attraction. Several times when theory and observation did not agree, these mathematicians were tempted to abandon the law, but in each case a little more labor, a few more neglected terms of a series, and theory was found to agree with observation. Since the time of the Herschels, double star astronomy and still more recently the spectrocopic binaries have testified in favor of the same law in distant stellar systems, as far as the accuracy of our observations is able to show. But there are two cases where the refinements of mathematical analysis, and the increased accuracy of observations have not succeeded in verifying the Newtonian law. Let us suppose that the solar system consists of the sun and Mercury, The planet Mercury would then describe an ellipse about the

*"The Secular Variations of the Elements of the Orbits of the Four Inner Planets." *Transactions of the American Philosophical Society*, Volume XXII, Part 2.

sun as a focus, due to their mutual attraction — an ellipse which would remain for all time fixed in size and position. As soon as we introduce another planet, as Venus, this equilibrium — if we may call it by such a term — is disturbed, and Mercury will now travel in an ellipse which varies continuously, but slowly, both in size and position. Each planet thus disturbs every other planet of the system. The actual path of any planet is, as a consequence, a very complicated curve about the sun, no point of which, however, is very distant from the fixed ellipse of the undisturbed planet.

If upon the quiet surface of water in a vessel, water is allowed slowly to drop, the surface will be disturbed, the particles rising and falling as the ripples spread over it. At the same time the surface will be slowly raised, due to the increase of volume of the water in the vessel. The result is that every particle of the surface has two distinct motions (*a*) periodic (motion in ripple) and (*b*) progressive (rising of the level). When the powerful mathematical analysis is applied to planetary perturbations a similar two-fold nature is found to exist. That is, we have periodic perturbations and secular variations. The periodic perturbations depend on the relative positions of the two planets in their respective orbits, that is, upon their heliocentric longitudes. They are completed in most cases in a few revolutions of the two planets. The secular variations, on the other hand, depend upon the position of the two orbits to one another, and are entirely independent of the positions of the planets in their respective orbits. A famous example of the first class is the "long period" of Jupiter and Saturn taking about 918 years to run its course — the time of a complete revolution of a point of conjunction. This perturbation displaces Jupiter a total of 21′ and Saturn 49′ in longitude. It was Laplace who brought, after much difficulty, this observed displacement into harmony with the Newtonian law. Examples of the second class are: (1) the line of Apsides of Neptune's orbit makes a complete revolution in 540,000 years: and (2) the line of nodes of Mercury a revolution in 166,000 years.

Some interesting facts can be stated regarding the second class of perturbations.

(*a*) Each planet's mean distance and consequently its year remains entirely free from any secular variation.

(*b*) The line of nodes and apsides revolve continuously.

(*c*) The inclination and eccentricity confine their variations within very narrow limits as shown by Laplace. [(*a*) and (*c*) insure the stability of the solar system].

(*d*) The eccentricities and inclinations being small, also the masses of the planets being small, in comparison with the sun; the secular variation produced in any element by the remaining planets can be computed separately, and added algebraically to get the total secular variation of that element. Modern investigations, which include higher powers in the development of the perturbing function than those of Laplace, indicate that these facts in regard to the stability of the solar system are not strictly true.

In 1818 the astronomer Gauss proved that if the mass of each planet were spread over its orbit to form an elliptic ring of infinitisimal thickness, and with a density at each point inversely proportional to the velocity of the body at that point, the mutual attractions of such rings would change their shapes and positions, and these changes would be exactly the same as the secular variations of the elements. The American astronomer; G. W. Hill, has given a very accurate method,* based on this theorem of Gauss, for the practical calculation of these secular variations. Since 1896 there have been appearing from time to time in the *Astronomical Journal* applications of Hill's Method by Professor Eric Doolittle, of the University of Pennsylvania. Final results for the four inner planets have recently been published.† Professor Doolittle finds that observation‡ gives an ex-

*On Gauss's Method of Computing Secular Perturbations. *Astronomical Papers of the American Ephemeris*, Vol. I.

†*Transaction of the American Philosophical Society*. Vol. XXII., Part 2.

‡Newcomb — "Astronomical Constants."

cess of 45″·4 per century over the calculated motion of Mercury's perihelion ; 10″·6 in case of the node of Venus ; and 8″·7 in the case of the perihelion of Mars. The smallest of these residuals is over three times its probable error. The remaining variations agree with observation. The explanation of the above residuals is one of the old unsolved problems of astronomy. The first is the most important and was first stated by Leverrier in 1845 as 35″ : Newcomb found it to be 43″. Since Leverrier's announcement astronomers have been looking for other masses — intra Mercurial planets — whose added attraction might harmonize the Newtonian law with observation. They used first the telescope, then later the camera during the total eclipses of the sun, but no images other than of known objects have ever been definitely seen. Director Campbell,* of the Lick Observatory, feels sure from the results of the Croker Eclipse Expedition to the South Seas in 1908, that there exists no planet as bright as the 8th magnitude nearer the sun than Mercury. Dr. Perrine was able, on this expedition to photograph stars to the 9th magnitude. He estimated that it would take about a million planets of the 8th magnitude, 30 miles in diameter to produce the observed motion of Mercury's perihelion. In 1895 Newcomb tried the hypothesis of placing a ring of finely divided material between the sun and Mercury, and a second hypothesis of a ring between Mercury and Venus having a mass of $\frac{1}{47\,000\,000}$ of the sun. Both rings were inclined to the ecliptic. Each of these suggestions he found gave rise to certain conditions which made them untenable. The zodiacal light which extends for more than 90° along the ecliptic, on the two sides of the sun, is supposed by astronomers to be sunlight reflected from finely divided material in the neighborhood of the sun. In 1906 H. H. Seeliger supposed this material to be arranged around the sun in the form of ellipsoids of revolution. He then computed the secular variation produced by the attraction of the ellipsoids : equated these to the residuals as determined by Newcomb in his "Astronomical Constants," excepting the four eccentricities which he considered as not per-

Popular Science Monthly, Vol. LXXIV.

turbed by the ellipsoids. The solution of these equations gave
*Density of inner ellipsoid = $2{\cdot}52 \times 10^{-11}$ times sun's density
Density of the outer ellipsoid = $0{\cdot}0026 \times 10^{-11}$ times sun's density
Total mass = 35000×10^{-11} times sun's density
Inclination of equator of inner ellipse = $6°{\cdot}95$
Longitude of node of inner ellipse = $40°{\cdot}03$.

The length of the axes of the ellipsoids and the position of the equator of the outer one were arbitrarily fixed. The total mass stated above has been computed as being comparable to $\frac{1}{3}$ of a cubic foot of water per cubic kilometer of space. It remains to be seen whether further observations upon the zodiacal light will strengthen this plausible hypothesis of Seeliger.

A. Hall† has tried the effect of changing the Newtonian law without adding any new masses to the solar system. His discussion is based on a theorem stated by Bertrand in 1873. That is — if the central force varies with the n^{th} power of the radius vector, the angle θ between the maximum and the minumum radii vectores will be $\theta = \frac{\pi}{\sqrt{n+3}}$. When $n = -2$, which is the Newtonian law, $\theta = \pi$ and the perihelion is fixed. He also found that a value of $n = -2{\cdot}00000016$ is sufficient to move Mercury's perihelion 43″ per century as found by Newcomb. There are no secular variations of the other elements due to this change in the value of n. But such a change Newcomb calculated would also make the moon's perigee move $1''{\cdot}5$ faster per year. E. W. Brown, of Yale, however, finds that the motion of the moon's perigee is in agreement with the Newtonian law.

The other old unsolved problem of gravitational astronomy was first stated by Halley, the friend of Newton, who found that the mean motion of the moon around the earth was slowly increasing — that is the month was getting shorter. He arrived at this conclusion from a comparison of ancient with modern solar eclipses. It was left for Laplace, however, to apparently

*Doolittle—Secular Variations of the Elements of the Four Inner Planets.
†*Astronomical Journal*, Vol. XIV.

explain this phenomenon. It can easily be shown* that the average disturbing effect of the sun upon the moon — the earth, moon and sun being in a line — varies, approximately, inversely as $(1 - e^2)^{\frac{1}{2}}$ where e is the eccentricity of the earth's orbit. Therefore if the earth's orbit becomes more circular (*i. e.* its eccentricity diminished), the average disturbing effect of the sun upon the moon during a revolution of the earth will be weakened, and as a consequence the earth's attraction will tend to accelerate the moon's mean motions and bring it closer to the earth. The computed secular variation of the earth's orbit shows that its eccentricity is slowly decreasing, sufficient to cause a shortening in the mean distance of the moon from the earth 14 ft. in 200 years, and if continued indefinitely would bring the moon down upon the earth. This decrease will continue, however, for about 24,000 years, the orbit of the earth becoming almost a true circle, after which interval the eccentricity will increase for several thousands of years. Laplace computed the acceleration of the moon's mean motion and found it to be 10″ per century. This was increased to 12″·5 by later astronomers, and agreed with the observed discrepancy obtained from the comparison of eclipses. In 1853 Adams reduced this to about half, finding that the former computations were rather rough approximations. The present value as found by Brown, and considered as accurate, is 5″·91. In 1877 Newcomb, from the comparison of the records of lunar eclipses, kept by Ptolemy and the Arabians, found the moon's observed acceleration to be 8″·3 per century. This still leaves a difference of 2″·4 per century between theory and observation. There are also some unexplained periodic perturbations of the moon, thought to be due to the action of planets, which complicates the solution of the problem of the moon's motion.

As a result, the tables, which predict the longitudes of the moon for given dates, do not agree with observation. For instance, in 1910·5 the moon's longitude was 4″·5 in excess of its predicted position.† Also the computed times of contact in

*Moulton's *Celestial Mechanics*, p. 242.

†*The Observatory*, No. 454, p. 391.

the case of solar eclipses are found to be in error a few seconds, and the plotted path of totality on the earth slightly shifted.

The early suggestion in 1856 by Ferrel that the discrepancy might be due to the lengthening of the unit of time, the day, by tidal friction or other causes seems to meet with the approval of most of the present day astronomers. Some, however, are suggesting a possible explanation through the finite propagation of gravitation based on the Principle of Relativity.* Still others suppose that during a lunar eclipse the earth acts as a partial absorber of the gravitational force between the sun and the moon.†

In conclusion it is well to remember that the discovery of aberration, nutation and the planet Neptune were due to the presence of small residuals; and that the whole structure of modern investigations depends upon the explanation of small quantitative changes. Some day this excess motion of Mercury and the moon may lead to the discovery of some phenomena as simple as those given above. The changing of the law seems farther from our minds than the presence of some subtle force like light pressure or magnetism.

THE COLLEGE OF THE CITY OF NEW YORK,
February 24, 1913.

* Poincaré *Comptes Rendus*, Vol. CXL., p. 1504: C. O. James, *Astronomical Journal*, 633-634.

†W. De Sitter, *The Observatory*, No. 454.

THE EXPRESSION OF PIVOT ERRORS BY A FORMULA

By R. Meldrum Stewart

Even the best measurements of pivot errors of a meridian circle or transit instrument are, of course, affected by accidental errors, and in the case of fairly good pivots these are no doubt larger than the actual deviations of the pivots from a smooth curve. It then becomes a question what pivot corrections should be adopted, both for the zenith distances at which the errors have been observed, and for intermediate zenith distances. The practice ordinarily followed is to plot the observed values and draw a smooth curve representing them as closely as possible. The objection to this proceeding is that it is not a definite one, and, what is perhaps more serious, that the amount of smoothing does not, as it should, depend on the accuracy of the original observations (for it is manifest that accurate observations should be smoothed less than inaccurate ones). It has seemed, therefore, that it would be advantageous, if possible, to obtain from the observations a definite formula which might be used in place of the smoothed curve, and from this formula to construct tables showing the zenith distances at which the pivot corrections change from unit to unit. In a recent series of measurements at the Observatory it was found that a good representation could be obtained by the use of a few terms of a Fourier series, and it seems probable that the values so adopted are more accurate than the actual observed values.

It is evident that a Fourier series can be made to represent the observed values to any required degree of accuracy ; for example, in the case where the pivot errors are observed at intervals of 5°, the use of 72 terms would reproduce the observed values exactly. Since, however, these observed values contain errors of measurement, it is probable that a more exact repre-

sentation of the actual pivot errors will be obtained by omitting the terms with small co-efficients; it then becomes a question simply of the number of terms to be retained.

It is evident that, the more accurate the original observations, the more closely the adopted curve should be made to represent them. Also, the accuracy of the observations is represented by the probable error of a single observation, computed in the usual way; since several complete sets of observations are always made, this is readily obtained. Hence the deviations of the adopted curve from the observed values should be a function of the observed probable error. But by treating these deviations as residuals they themselves may be utilized to form another probable error, which represents the accuracy with which the adopted curve reproduces the observed values. The most obvious assumption is that these two probable errors should be made equal; that is, that sufficient terms should be included in the Fourier series (choosing always the largest terms) to make its representation of the observed values equally accurate with the representation of the true values by the observations themselves.

Freed from technicalities, the above process simply amounts to drawing a smoothed curve in a particular way, with the adoption of a criterion for the amount of smoothing. The tentative adoption of a particular number of terms amounts to drawing a trial curve; if upon examination it is found that it is an even chance that the discrepancies between the curve and the observed values are due to errors of observation, the curve is adopted; if not, another trial curve is formed, and the process repeated until the desired result is attained.

The statement has been made that the criterion adopted (that of equality between the two probable errors) is incorrect, and a different one has been suggested, *viz.*, that sufficient terms of the Fourier series should be included to make the probable error deduced therefrom a minimum. It seems to the writer, however, that a perusal of the preceding paragraph will establish the fact that his criterion is essentially logical and reason-

able. The suggested criterion, not to mention the fact that it takes no account of the known accuracy of the observations (which can be measured independently), and that the whole principle involved in its application (that of "minimum probable error") is at least very seriously open to question, is manifestly entirely inapplicable in the present case. For it may be shown that in the attempt to represent any such observed series of quantities by a Fourier expansion, the computed probable error diminishes continually as the number of terms included increases; the proof of this theorem is elementary. Thus the adoption of this criterion would necessarily be synonymous with the use of a curve totally unsmoothed, that is, of the actual observed values.

It has been mentioned above that the use of the Fourier series amounts to drawing a smoothed curve in a particular way. It may be conceivable (though it does not appear in any way certain) that in some special case this particular way might not be suitable, *i.e.*, that a limited Fourier series might not be applicable at all. This could probably occur only in the case of very irregular pivots, where the majority of the co-efficients in the complete Fourier series would be comparatively large. Even in this case the only fact that seems clear is that the number of terms necessary to give a satisfactory representation would be so large that the labor of computation would be prohibitive. In any case an examination of the residuals from the adopted curve will readily show whether any marked runs occur; if not the formula may be safely adopted. In the writer's judgment the occurrence of marked runs in the residuals would simply indicate that the pivots were decidedly irregular, and stood in need of re-grinding.

The actual determination of the pivot errors of the meridian circle at this observatory, referred to at the outset, was made by the microscopic method. Eight complete measurements of pivot errors were made; the probable error of a pair of microscope pointings (treated as a single observation) was found to be ·0015 sec.; five cosine terms and five sine terms of the Fourier expansion (which may be combined into five cosine terms) were

found to be sufficient to reduce the computed probable error to the same value. When the results are put in the form of a correction to the observed collimation it may be shown that terms involving the sine and cosine of the zenith distance have no effect; consequently these were omitted.

The resulting formula is

$$\Delta c = {}^{s}\cdot0010 \cos(2\theta - 188°29') + {}^{s}\cdot0117 \cos(3\theta - 3°17') + {}^{s}\cdot0021 \cos(4\theta - 59°45') + {}^{s}\cdot0008 \cos(5\theta - 121°58')$$

θ being the zenith distance. The residuals from the formula were satisfactorily small (in no case exceeding ·002 sec.), and appeared to be purely accidental.

Values of the formula were computed for different zenith distances, and from these a table was prepared giving the zenith distances at which the value of Δc changed from one unit (in terms of ·001 sec.) to the next; it is this table which is used in the reduction of transits.

It may be remarked that the strictly logical method of procedure would be to treat the sine and cosine terms independently. Thus, if the complete representation is given by

$$\Delta c = a_0 + a_1 \cos\theta + a_2 \cos 2\theta + a_3 \cos 3\theta + \ldots\ldots + b_1 \sin\theta + b_2 \sin 2\theta + b_3 \sin 3\theta + \ldots\ldots$$

the terms with largest co-efficients should be chosen without combining the sine and cosine terms in pairs. This mode of procedure would in the actual case considered have changed the adopted formula slightly, in that the term involving sin 2θ (co-efficient $-$ ·0002) would have been omitted, and that involving sin 12θ (co-efficient $-$ ·0005) would probably have been included. Had the tables not been completed originally with the formula as given above, this change would have been made. As, however, the change in adopted pivot errors would have been extremely minute, it has not, up to the present at least, been thought worth while to make the change.

Dominion Observatory,
Ottawa, Canada,
April, 1913.

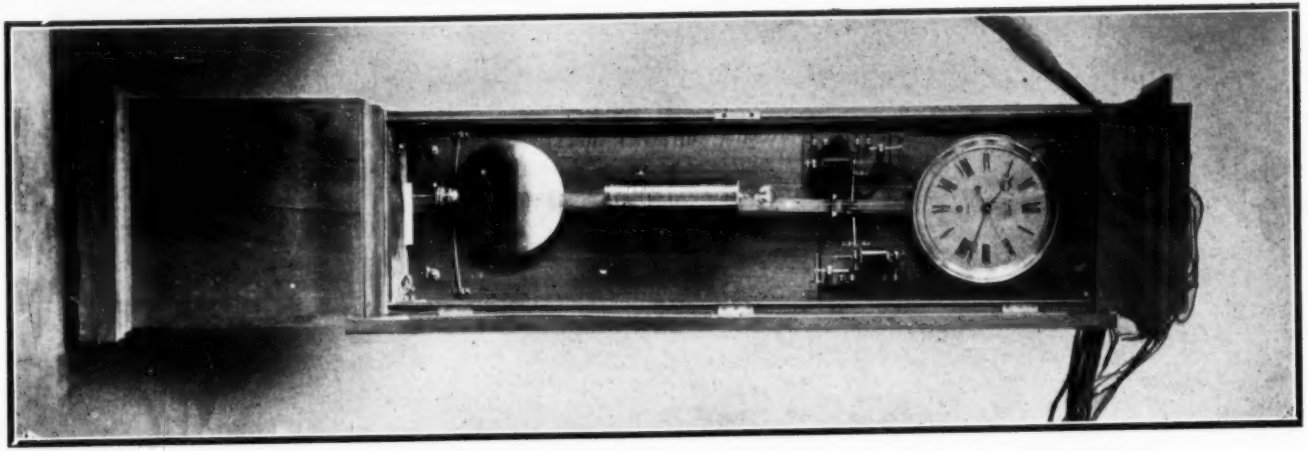

FIGURE 2.

SECONDARY STANDARD CLOCK WITH THE NEW REGULATING ATTACHMENTS

A NEW FORM OF CLOCK SYNCHRONIZATION

By R. Meldrum Stewart

IN connection with the Time Service at the Dominion Observatory there is a system of some three hundred electric secondary clocks distributed throughout the principal Government offices in the city, all under control of the mean time primary clock at the Observatory. In arranging for the operation of these the group principle was adopted ; that is, a group of electric dials (clocks containing no going mechanism of their own), in a single building or several adjacent buildings, are operated by electrical impulses derived from a secondary master-clock situated in a convenient location, usually in the same building. These secondary master-clocks are complete in themselves, and capable of running and operating their dials independently ; they are, however, normally kept synchronized by signals sent out by the primary clock at the Observatory.

The style of synchronization in use up to a few months ago was that usually known as the Riefler system. In each of the synchronized clocks was a "synchronizing" electro-magnet situated below and to one side of the end of the pendulum rod ; attached to the pendulum was a small armature of soft iron, which would be attracted by the electro-magnet whenever current flowed through the latter. A current controlled by the primary clock was arranged to flow through the synchronizing magnet every alternate second ; thus the pendulum of the synchronized clock was forced to swing in synchronism with that of the primary.

This system works very satisfactorily where the synchronization wires are not liable to serious interruptions ; in the present case, however, these wires were several miles in length, and passed through telephone cables and a telephone exchange. In

the event of an interruption lasting a number of hours it was always possible that one or more of the synchronized clocks might gain or lose almost a complete second ; in this case, when the line was repaired, the impulses of the synchronizing magnet would be in opposition to the motion of the pendulum, and the clock in question would be almost sure to stop. To guard against this it was necessary to introduce an automatic cut-out, by means of which any abnormality in the synchronization current would automatically disconnect the synchronized clocks and allow them to run independently until they were visited by the official in charge and again connected normally.

With the system thus improved, no dangers were to be apprehended on that score ; the cut-out, however, proved so sensitive that it responded to many momentary derangements which would have been absolutely harmless ; on this account the clocks were set free from control on an average perhaps once a week, or sometimes oftener, involving many otherwise unnecessary visits for the purpose of re-connecting them. It was decided, therefore, to abandon the style of synchronization in use, and replace it by that described below.

In this form, the synchronizing magnet is replaced by two, situated one on each side of the pendulum rod, not very far from its upper extremity ; their function is simply to automatically add or remove small weights from the pendulum as required. Three other relays are required ; these were all in use before.

A diagram of the electrical connections required is shown in Fig. 1. *B* is a relay closed for one second every minute by the synchronized clock ; it serves also to work the electric dials in that particular group by means of the local battery *E* (this circuit is not shown). *C* is a relay operated from the Observatory by the primary clock ; it is alternately open and closed during alternate seconds. *D* is a differentially wound, neutrally adjusted polar relay. *A* and *R* are the two synchronizing magnets, situated in the clock case ; when no current passes through either magnet the small weight attached to the armature of *R* rests on a shelf on the pendulum rod, while that attached to the

armature of *A* is suspended ; the clock is rated to run approximately right with the weights in this position. It will thus be seen that the passage of a current through *A* drops an additional

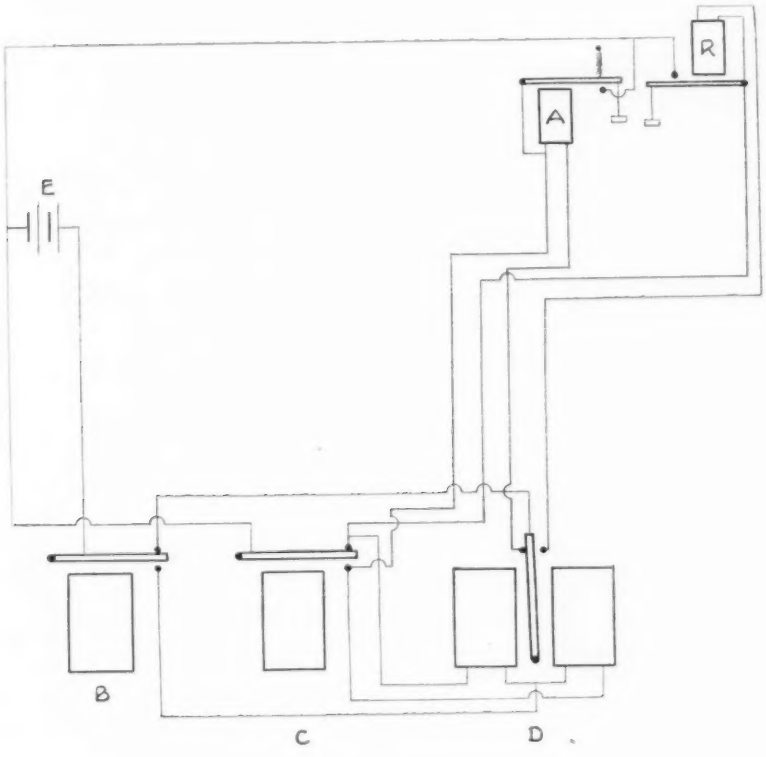

FIGURE 1.

DIAGRAM SHOWING ELECTRICAL CONNECTIONS.

weight upon the pendulum and accelerates the clock ; similarly the action of *R* removes a weight and retards it.

If the clocks are in perfect synchronism the relays *B* and *C*

will both close at the 59th second of every minute, and both open at the 60th ; it is the coincidence of the opening of the relays which forms the automatic test of synchronism. It will be seen from the diagram that while the armature of *B* is down, current from the local battery *E*, passing through the armature to the lower "point" of *B*, flows through the right or left coil of *D* according as the armature of *C* is down or up. Thus at the instant of the opening of *B* (the 60th second of every minute), the armature of *D* will be to the right or left according as the armature of *C* is down or up, that is, according as the synchronized clock is fast or slow ; and since *D* is neutrally adjusted its armature will remain in the same position until it is set at the next following minute. As soon as *B* has opened (at the 60th second) current from the battery flows by way of its armature and the upper contact point, to the armature of *D*, and thence, depending on the position of the latter, to the proper one of the magnets *A* and *R*, returning through the points of *C* to battery. The passage of this current through the points of *C* is necessary in order that the controlled clock may be left running free in case of accident to the synchronization line. An examination of the diagram will show that, after the "setting" of the armature of *D*, no current can flow through the corresponding one of the magnets *A* and *R* until the armature of *C* has changed its position from down to up or *vice versa* ; hence no action can take place unless *C* is working. After the synchronizing magnet is closed, subsequent movements of the armature of *C* have no effect, since the latter is then short-circuited by a connection made by the arm of the synchronizing magnet as shown in the diagram.

This type of synchronization, from its nature, is necessarily restricted to the case where both synchronizing and synchronized clocks control suitable electric circuits ; its principal advantage is that there is no possibility of stopping the controlled clock by interferences with the synchronizing current, an advantage which, so far as I am aware, is not shared by any other method.

The controlled clocks are in this particular case not of the

highest accuracy, and are exposed to considerable vicissitudes of temperature; to ensure satisfaction the correcting weights are made capable of taking care of a variation in rate of eight or ten seconds per day; the synchronization is thus effective to within about a hundredth of a second. In the case of a high grade clock very much smaller correcting weights could be used, and the interval between the automatic comparisons could be increased to perhaps an hour.

DOMINION OBSERVATORY,
OTTAWA, CANADA,
April, 1913.

NOTES FROM THE DOMINION OBSERVATORY

MAGNETIC OBSERVATIONS

During the season of 1912, sixty stations lying east of Ottawa in the Provinces of Quebec, New Brunswick and Nova Scotia, besides Ottawa and Agincourt, were occupied, in continuation of the systematic survey of Canada, undertaken by the Observatory.

The instruments used were: a Tesdorpf fibre declinometer, No. 1977, for determining declination and horizontal intensity; a Dover dip circle, No. 145, for inclination; a Watt 5-inch theodolite for time, azimuth, and latitude; and a mean time half-seconds pocket chronometer, Kittel No. 261, for determining the time of an oscillation of the intensity magnet,—being the same instruments as used the previous season, except that a Watt replaced a Troughton & Simms, and Kittel No. 261 replaced Bond No. 511.

The method of observing was practically the same as that followed heretofore. Latitude was obtained from meridian altitudes of the sun, circle left and circle right. Time and azimuth were obtained by observations at about 9 a.m. and 3 p.m., on the sun, circle left and circle right. With few exceptions the magnetic declination was obtained by taking the mean of the eastern and western elongations; the eastern elongation occurring usually between 7 and 8 a.m. and the western one between 1 and 2 p.m. Whenever possible the observing was commenced earlier and continued later, in order to insure obtaining the extreme elongation. Whenever the magnetic conditions are normal the

deduced declination, obtained as above, is quite satisfactory. In addition to the elongations, there were taken throughout the day a number of observations which were not used to obtain a mean value of declination, but serve for a study of the diurnal variation curve. At least two observations were taken for dip, one in the morning and one in the afternoon. The horizontal intensity was obtained from a set taken in the morning and one in the afternoon; a set consisting of deflections and oscillations.

In general, a complete set of observations at any station consisted of, at least, the following, with the approximate local mean time of each.

Declination (eastern elongation)	7.30 to 8.30 a.m.
Azimuth	9.00
Declination	9.30
Dip	10.00
Declination	10.30
Deflections and oscillations	11.15
Latitude	12.00
Declination (western elongation)	1.00 to 2.00 p.m.
Oscillations and deflections	2.30
Azimuth	3.00
Dip	3.30
Declination	4.15

At many of the stations all the magnetic observations were duplicated.

Before commencing and after completing the field work for the season, comparisons were made between Tesdorpf magnetometer No 1977 and the standard instruments of the Magnetic Observatory at Agincourt; similarly comparisons were made between the Dover dip circle No. 145 and the Dover dip circle No. 200, which was taken as the standard previous to 1912.

The Ottawa Observatory being now in possession of a Toepfer earth inductor, No. 1911, it is used as a standard for dip.

A number of stations were occupied as repeat stations, and

the annual rate of change is given in the second table following.

Probably in the whole range of observational work there are no observations that so often fail the expectations and *a priori* conclusions as do magnetic observations. Especially when the annual change is deduced from a short time interval of a few years are we apt to find anomalies, or apparent anomalies due to our ignorance.

A longer series, however, tends to smooth out curves and make them more amenable to geographic distribution of stations. But let this not be understood to mean that it is the desire to smooth out curves. Facts are always wanted, wherever they lead.

In the first table are given the magnetic elements obtained at the stations in 1912; and in the other table the annual change. All the observations were made by C. A. French, of the Observatory staff.

MAGNETIC RESULTS IN 1912.

Station	Latitude	Longitude	Date	Declination	Dip	Hor Int.	Total Int.
	° ′	° ′		° ′	° ′	C.G.S.	C.G.S.
Ottawa	45 23·6	75 43·0	Apr.	13 10·7W.	75 40·1	·15070	·60880
*Agincourt	43 47·0	79 16·0	"	6 13·0W.	74 39·4	·16184	·61163
Buckingham Jct.	45 33·5	75 25·5	May 2 - 4	13 43·7W.	75 32·8	·15280	·61218
Papineauville	45 37·4	75 00·8	" 6 - 9	13 25·9W.	75 45·8	·15104	·61416
Calumet	45 39·6	74 38·1	" 10 - 11	13 20·3W.	75 38·0	·15189	·61215
Lachute	45 40·0	74 20·1	" 14 - 15	13 59·3W.	75 45·5	·15118	·61451
Ste. Therese	45 39·2	73 51·6	" 16 - 18	15 20·5W.	75 42·6	·15012	·60818
Montreal	45 30·3	73 34·7	" 21 - 22	15 27·4W.	75 37·0	·15027	·60492
Terrebonne	45 42·8	73 39·8	" 23 - 24	14 54·4W.	75 50·5	·14848	·60703
Berthier	46 06·3	73 11·4	" 25	16 50·7W.	76 02·6	·14692	·60914
Louiseville	46 16·5	72 56·4	" 27 - 28	15 56·0W.	76 01·9	·14670	·60774
Three Rivers	46 21·0	72 32·2	" 29 - 31	16 00·2W.	75 58·3	·14760	·60891
La Perade	46 35·0	72 12·9	June 3 - 4	17 25·6W.	76 07·4	·14542	·60633
Ponte Rouge	46 46·0	71 42·7	" 4-5-6	17 26·9W.	76 29·7	·14162	·60647
St. Valier	46 52·6	70 48·3	" 10 - 12	19 10·0W.	76 12·3	·14378	·60298

* The values for Agincourt were taken from the JOURNAL OF THE ROYAL ASTRONOMICAL SOCIETY OF CANADA.

** Local disturbance.

MAGNETIC RESULTS IN 1912—(*Continued*)

Station	Latitude		Longitude		Date		Declination		Dip		Hor. Int.	Total Int.
	°	′	°	′			°	′	°	′	C.G.S.	C.G.S.
L'Islet	47	07·0	70	20·2	June	14 - 15	19	31·4W.	76	18·5	·14271	·60291
Ste. Anne	47	22·7	70	02·8	"	17 - 18	20	15·1W.	76	23·1	·14207	·60353
St. Helène	47	36·0	69	43·8	"	18 - 20	20	53·8W.	76	28·5	·14100	·60289
Rivière du Loup	47	51·6	69	32·5	"	21 - 22	21	06·8W.	76	33·5	·14049	·60437
Trois Pistoles	48	08·5	69	10·4	"	24 - 25	21	50·0W.	76	42·4	·13924	·60555
Bic	48	23·6	68	43·6	"	26 - 27	22	31·8W.	76	45·6	·13878	·60594
Ste. Flavie	48	35·6	68	14·6	"	28 - 29	23	42·1W.	76	50·9	·13769	·60515
Sayabec	48	34·3	67	43·5	July	1 - 2	23	47·5W.	76	50·1	·13679	·60059
Causapscal	48	21·2	67	17·2	"	3	23	39·5W.	76	32·0	·13931	·59821
Matapedia	47	58·5	66	57·8	"	5 - 6	23	21·0W.	76	28·7	·13942	·59628
Dalhousie Jct.	48	02·8	66	32·4	"	9	24	15·6W.	76	19·0	·14073	·59491
Jacquet River	47	55·4	66	00·5	"	10 - 11	24	19·4W.	76	19·8	·14104	·59935
Bathurst	47	37·2	65	36·8	"	12 - 13	24	13·0W.	75	59·8	·14359	·59339
Bartibogue	47	18·0	65	34·1	"	15 - 16	23	22·8W.	75	45·8	·14576	·59269
**Newcastle	47	00·2	65	34·5	"	17 - 18	23	27·9W.	75	36·8	·14663	·59013
Kent Jct.	46	35·1	65	17·1	"	20	22	44·6W.	75	25·3	·14850	·58997
Canaan	46	15·1	65	04·1	"	26 - 27	22	24·6W.	75	23·0	·14888	·58998
Moncton	46	05·0	64	48·2	"	29 - 30	22	41·5W.	75	01·9	·15210	·58889
Memramcook	46	01·0	64	30·0	"	31 Aug. 2	22	31·9W.	74	57·3	·15264	·58803
Amherst	45	50·6	64	11·4	Aug.	5	22	50·8W.	74	37·4	·15612	·58876
Oxford Jct.	45	42·5	63	53·4	"	7 - 8	22	25·8W.	74	41·8	·15490	·58901
Folleigh	45	33·7	63	32·8	"	9 - 10	23	04·1W.	74	18·6	·15918	·58861
Truro	45	21·3	63	16·3	"	14 - 15	22	31·2W.	73	51·2	·16263	·58482
Truro	45	21·3	63	16·3	Oct.	5	22	30·2W.	73	50·8		
Elmsdale	44	59·2	63	30·8	Aug.	16 - 17	22	16·2W.	73	47·9	·16200	·58062
Halifax	44	37·6	63	34·8	"	20 - 21	21	37·6W.	73	52·3	·16130	·58064
Black Point	44	39·1	63	59·4	"	23 - 26	21	40·5W.	73	53·6	·16149	·58209
Chester	44	33·2	64	14·0	"	28	21	24·3W.	73	50·2	·16239	·58335
Lunenburg	44	22·5	64	18·0	"	29 - 30	20	49·6W.	73	53·0	·16188	·58315
New Germany	44	33·1	64	42·9	"	31 Sep. 1	21	01·1W.	73	51·6	·16232	·58390
**Liverpool	44	03·1	64	43·8	Sept.	3 - 4	19	55·1W.	74	48·8	·15226	·58123
Shelburne	43	45·5	65	20·1	"	7 - 9	19	39·3W.	73	39·9	·16362	·58177
**Barrington	43	34·2	65	35·7	"	10 - 11	19	27·5W.	73	35·1	·16426	·58126
**Yarmouth	43	49·8	66	06·3	"	12 - 13	17	25·7W.	74	14·3	·15787	·58118
Weymouth	45	25·0	65	58·1	"	14 - 16	19	58·6W.	73	59·8	·16190	·58725
Annapolis	44	45·0	65	31·2	"	18 - 19	20	49·0W.	74	04·0	·16085	·58594
Middleton	44	57·2	65	04·5	"	23 - 24	20	53·2W.	74	10·0	·15972	·58540
Windsor	44	59·6	64	09·0	"	25 - 26	21	48·1W.	73	58·5	·16112	·58305
**Mulgrave	45	36·3	61	23·3	"	28 - 30	24	23·5W.	73	47·3	·16137	·57799
**Mulgrave (Aux. Stn.)	45	36·3	61	23·3	Oct.	1	24	30·7W.	73	46·6	·16118	·57691
Sydney	46	08·8	60	12·3	"	3 - 4	25	43·2W.	74	11·8	·15666	·57537
Petitcodiac	45	57·5	65	09·3	"	7 - 8	22	14·8W.	75	01·7	·15272	·59118
Norton	45	38·4	65	40·7	"	9 - 10	21	35·9W.	74	44·8	·15514	·58969
St. John	45	16·8	66	02·6	"	11 - 12	20	48·2W.	74	21·5	·15911	·59012
Fredericton Jct.	45	40·5	66	38·1	"	14 - 15	21	22·5W.	75	02·2	·15313	·59306
Boiestown	46	27·3	66	25·3	"	16 - 17	22	00·3W.	75	29·3	·14810	·59103
Fredericton	45	57·0	66	38·4	"	17 - 18	21	10·2W.	75	24·0	·14905	·59130
Woodstock	46	09·6	67	34·8	"	19 - 21	20	14·6W.	75	29·0	·14884	·59379
Edmundston	47	22·1	68	19·5	"	22 - 23	21	39·7W.	76	16·6	·14186	·59796
*Ottawa	45	23·6	75	43·0	Nov.	8 - 11	13	12·9W.	75	40·2	·15058	·60839
*Agincourt	43	47·0	79	16·9	"		6	13·7W.	74	40·3	·16166	·61131

Annual Change

Station	Date	*Obs.	Declination	Dip	Hor. Int	Date	Obs.	Declination	Dip	Hor. Int.	Aver. Dec.	Annual Change Dip	Hor. Int.
			° ′	° ′	C.G.S.			° ′	° ′	C.G.S.	′	′	C.G.S.
Ottawa	Oct. 1906	C.I.	12 44·4W.	75 33·1	·15222	Nov. 1912	D.O.	13 12·9W.	75 40·2	·15058	− 4·7	+ ·2	− ·00027
Agincourt	Sept. 1906	M.S.	5 47·3W.	74 35·9	·16388	Nov. 1912	M.S.	6 14·2W.	74 40·4	·16163	− 4·4	+ ·7	− ·00031
Montreal	Aug. 1905	C.I.	14 40·1W.	75 38·2	·1512	May 1912	D.O.	15 27·4W.	75 37·0	·15027	− 7·0	− ·2	− ·00014
Three Rivers	Sept. 1906	C.I.	15 26·1W.	75 57·1	·14825	May 1912	D.O.	16 00·2W.	75 58·3	·14760	− 6·0	+ ·2	− ·00013
Rivière du Loup	Sept 1906	C.I.	20 38·7W.	76 34·1	·1408	June 1912	D.O.	21 03·8W.	75 33·5	·14049	− 4·9	− ·1	− ·00035
Matapedia	Nov. 1907	D.O.	22 53·3W.	76 35·3	·1387	Ju'y 1912	D.O.	23 21·0W.	76 28·7	·13942	− 5·9	− 1·3	+ ·00015
Bathurst	Nov. 1907	D.O.	23 39·4W.	76 03·9	·1431	July 1912	D.O.	24 13·0W.	75 59·8	·14359	− 7·2	− ·9	+ ·00010
(*a*) Newcastle	Nov. 1907	D.O.	22 47·4W.	75 36·2	·1465	July 1912	D.O.	23 27·9W.	75 36·8	·14663	− 8·7	+ ·1	+ ·00003
Moncton	Oct. 1907	D.O.	22 15·0W.	75 07·8	·1515	Ju'y 1912	D.O.	22 41·5W.	75 01·9	·15210	− 5·6	− 1·2	+ ·00013
Truro	Oct. 1907	D.O.	21 50·7W.	73 52·5	·1618	Aug. 1912	D.O.	22 31·2W.	73 51·2	·16263	− 8·4	− ·3	+ ·00017
Truro	Oct. 1907	D.O.	21 50·7W.	73 52·5	·1618	Oct. 1912	D.O.	22 30·2W.	73 50·8		− 7·9	·3	
Halifax	Sept. 1905	C.I.	20 54·8W.	73 58·8	·16187	Aug. 1912	D.O.	21 37·6W.	73 52·3	·16130	− 6·2	0·0	− ·00008
Halifax	Sept. 1905	C.I.	20 54·8W.	73 58·8	·16187	Sept. 1911	M.S.	21 35·4W.	73 49·8	·16149	− 6·8	− 1·5	− ·00006
Black Point	Sept. 1905	C.I.	21 03·8W.	73 59·5	·16191	Aug. 1912	D.O.	21 40·5W.	73 53·6	·16149	− 5·3	− ·8	− ·00006
(*b*) Mulgrave	Nov. 1907	D.O.	24 13·3W.	73 53·6	·1611	Sept. 1912	D.O.	24 23·5W.	73 47·3	·16137	− 2·1	− 1·3	+ ·00005
Mulgrave	Nov. 1907	D.O.	24 13·3W.	73 53·6	·1611	(*A*) Sept. 1912	D.O.	24 30·7W.	73 46·6	·16118	− 3·6	− 1·4	+ ·00001
Sydney	Sept. 1905	C.I.	25 12·9W.	74 22·8	·15656	Oct. 1912	D.O.	25 43·2W.	74 11·8	·15666	− 4·3	− 1·6	+ ·00001
St. John	Oct. 1907	D.O.	20 10·8W.	74 24·8	·15920	Oct. 1912	D.O.	20 48·2W.	74 21·5	·15911	− 7·5	− 0·7	− ·00002
Edmundston	Sept. 1906	C.I.	21 07·7W.	76 18·8	·14228	Oct. 1912	D.O.	21 39·7W.	76 16·6	·14186	− 5·3	− 0·4	− ·00007

*C. I.—Carnegie Institution. D. O.—Dominion Observatory. M.S.—Meteorological Service.

(*a*) Station (1912) is about 400 ft. south of station (1907). Local disturbance exists.

(*b*) New station was selected, as station of 1907 was not available.

(*A*) is an auxiliary station, selected for testing for local disturbance, which evidently exists. It is about 450 ft. northwesterly from the new station and about 50 ft. easterly from the station of 1907.

Note.—Westerly declination is increasing.

Dominion Observatory,
Ottawa, Canada,
May, 1913.

Otto Klotz.

NOTES FROM THE METEOROLOGICAL SERVICE

Summary Report of the Weather in Canada
June, 1913.

Temperature. – In British Columbia and the Prairie Provinces the mean temperature for the month exceeded the normal by from 2° to 4° in most localities. Locally in Southeastern Alberta, however, the positive departure amounted to over 7°. Over nearly the whole of Ontario mean temperatures were from a fraction of a degree to 3° below normal; but in the Lake Superior region, and in the districts at the west end of Lake Ontario, a positive departure was recorded. In Quebec and the Maritime Provinces temperatures were everywhere below average, the departure ranging from a fraction of a degree to nearly 3°. Pronounced heat prevailed at times in all parts of the Dominion, and maximum readings of near 90° or over were recorded in many localities.

Precipitation. —The rainfall during June was seriously in defect over the greater part of Canada. In parts of Southern British Columbia, and in Alberta and Southern Saskatchewan, however, there was considerable excess. In Ontario there was a deficiency in the rainfall in all districts, amounting in some cases to 75 per cent of the normal. In Quebec and the Maritime Provinces, likewise, the precipitation was everywhere below average, the negative departure varying from 15 per cent to 85 per cent of the normal amount.

JULY, 1913.

Temperature.—The mean temperature was below the average over a large portion of the Dominion, the exceptions being Vancouver Island, and a considerable section of Central and Eastern Ontario and Western Quebec. The positive departures were, as a rule, however, quite small, in most places 1° or less. Negative departures were also in most places comparatively small, the largest being 3° to 4° in Western Manitoba and Southern Saskatchewan.

Precipitation. — The rainfall for the month was below the normal over a portion of British Columbia, Southern Alberta, the southern and eastern districts of Manitoba, the greater part of Ontario and in Western Quebec; whereas quite heavy rains, amounting to or exceeding the normal, occurred in the other portions of the country. With the exception of the southern districts of Alberta and Manitoba, the moisture in the West was ample for the rapid growth of all grains, while in Ontario, with the exception of a few localities, the crops suffered considerably from drought. Over the greater part of Quebec and the Maritime Provinces the rainfall was sufficient for all vegetation. The total precipitation was particularly heavy in the central and northern districts of Quebec.

Temperatures for June and July, 1913

Station	June		July	
	Highest	Lowest	Highest	Lowest
Yukon				
Dawson	88	28	82	34
British Columbia				
Atlin	76	28	74	34
Agassiz	84	40	91	45
Barkerville	72	31	79	32
Kamloops	88	44	99	43
New Westminster	82	44	89	43
Prince Rupert	72	44	70	48
Vancouver	77	44	83	44
Victoria	78	43	85	45
Western Provinces				
Battleford	88	35	88	45
Broadview				
Calgary	72	46	86	38
Carman				
Edmonton	89	32	86	41
Medicine Hat	97	46	98	43
Minnedosa	89	30	90	42
Moose Jaw	88	34	90	37
Oakbank	89	32		
Portage la Prairie	92	31	90	45
Prince Albert	84	35	86	42
Qu'Appelle	86	33	84	36
Regina	86	34		
Swift Current	89	37	92	36
Winnipeg	91	34	88	46
Ontario				
Agincourt	94	35	94	45
Aurora	91	32	91	42
Bancroft	93	29	94	37
Barrie			94	40
Beatrice	89	32	86	38
Birnam	91	31	90	41
Bloomfield	88	38	92	47
Brantford	92	33	95	43
Bruce Mines	90	31	85	42
Chatham	97	36	96	45
Clinton	90	29	93	38
Cottam	95	30		
Gravenhurst	93	30	90	40
Guelph	90	34	91	43
Haliburton	93	27	94	35
Hamilton				
Huntsville	91	29	89	40
Kenora				
Kinmount	92	28		
Kingston	86	38	90	48
Lakefield				
London	92	27	94	40
Lucknow	92	28	95	36
Madoc	91	35	95	44
Midland			91	50
North Gower				
Otonabee				
Ottawa	90	38	93	46
Owen Sound				
Paris	93	37	96	43
Parry Sound	90	34	97	45
Peterboro'	88	34	92	43
Port Arthur	90	31	82	42
Port Burwell	81	36	85	42
Port Dover	91	35	92	49
Port Stanley	91	34	83	54
Ronville	92	28	88	38
Sarnia				
Southampton	91	35	90	42
Stonecliffe	96	31	92	40
Stony Creek	92	36	94	45
Stratford				
Toronto	95	38	95	50
Uxbridge	91	32	91	43
Wallaceburg	92	34	91	43
Welland	87	39		
White River			79	39
Quebec				
Brome	82	32	89	43
Father Point	77	33	76	42
Montreal	88	42	93	51
Quebec	85	37	90	48
Sherbrooke				
Maritime Provinces				
Charlottetown	74	35	83	47
Chatham	82	35	92	50
Dalhousie	72	30	82	43
Fredericton	83	34	91	47
Halifax	78	33	90	47
Moncton	82	32	80	41
St. John	74	41	80	52
St. Stephen	82	33		
Sussex	75	32	76	46
Sydney	77	30	84	36
Yarmouth	72	38	76	46

Earthquake Records by the Milne Seismograph

TORONTO

R. F. Stupart, Director.

P.T. = Preliminary Tremors. L.W. = Large Waves. A.C. = Air Currents.

Time is Greenwich Civil Mean Time, 0 or 24 h = midnight.

No.	Date 1913	P. T. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Durat.	Remarks
		h m	h m	h m	h m	mm.	h m	
1256	June 4	10 25·0?	10 55·8	11 4·4	12 15·3? 12 29·8	0·3	2 4·8	No defined max.
1257	" 14	8 46·0	8 51·7 8 56·5	8 59·3	9 51·6	0·3	1 5·6	Merged into 1258.
1258	" 14	9 53·4	10 9·3	10 20·3	11 26·9	2·0	1 33·5	
1259	" 14	11 46·0	11 49·8	11 52·1	12 18·2	0·2	0 32·2	P. Ts. may be merged into 1258.
1260	" 22	14 0·8	14 17·3	14 28·5	16 34·8 16 58·3	1·7	2 57·5	No distinct max.
1261	" 26	5 10·2	5 25·4	6 25·6	8 30·3? 8 46·2	4·3	3 36·0	A marked dis.
1262	July 6	17 9·4? 13·5			18 8·0		0 58·6	Principal movements lost. Attending to instrument.
1263	" 7	18 9·8?			19 50·5	0·2	1 40·7	
1264	" 8	8 48·2			9 2·2	0·1	0 14·0	
1265	" 8	22 31·0?			23 48·4	0·05	1 17·4	Beginning doubtful.
1266	" 9	0 20·7	0 23·7	0 26·8	0 55·6	0·8	0 34·9	A well defined dis.
1267	" 12	11 1·5			A. C.	0·1		
1268	" 22	7 27·4			8 49·1	0·1	1 21·7	
1269	" 24	9 14·8			9 28·8	0·05	0 14·0	
1270	" 25	A. C.	12 51·3	12 56·6	14 21·5	2·6		A.C. at beginning.

Period 17·7 seconds. 1 mm. = 0″·59.

VICTORIA, B. C.

E. B. REED, SUPERINTENDENT.

No.	Date 1913	P.T. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Durat.	Remarks
		h m	h m	h m	h m	mm.	h m	
1261	June 4	10 21·2	10 45·6	11 3·3?	12 37·0	1·2	2 16·8	
1262	" 14	8 50·9	8 58·4	9 2·7	9 32·0	2·0	0 41·1	
1263	" 14	9 54·9?	10 16·8	10 28·3	11 28·0	0·8	1 33·1	
1264	" 14	12 1·3			12 10·2?	0·1	0 8·9	
1265	" 22	13 57·2	14 5·1	14 15·2	15 59·2	2·9	2 2·0	Real P.Ts. may not have been recorded
1266	" 26	5 9·3	5 19·9) 5 26·1)	5 52·7	8 28·8) 8 48·2)	6·2	3 38·9	Real P.Ts. may not have been recorded
1267	July 6	17 3·3			17 54·3	0·1	0 51·0	
1268	" 7	10 6·9			10 31·6	0·1	0 24·7	
1269	" 7	18 6·0	18 20·4	18 38·6	19 19·2	1·3	1 13·2	Marked little dis.
1270	" 8	8 37·9	8 38·9	8 39·1	8 45·9	0·8	0 8·0	
1271	" 8	22 33·6			Merged into 1272	0·05		
1272	" 9	0 6·6?	0 8·1	0 8·6	0 26·8	3·0	0 20·2	
1273	" 12	10 44·8		11 22·7	11 56·0	0·2	1 11·2	
1274	" 22	7 15·4	7 19·3	7 38·9	8 12·1	0·3	0 56·7	Marked thick'ings. No defined max.
1275	" 25	13 0·0?	13 8·5	13 9·9	13 47·4	0·2	0 47·4	No defined max.

Period 18 seconds. 1 mm. = 0″·54

J. Y.

MAGNETIC OBSERVATIONS

The magnetic forces, as indicated by the photographic records secured at Agincourt, have continued very stable during June and July.

On the 1st of June a moderately active disturbance began at 2 a. m., and lasted until 11 p. m., the amplitude in *D* was 39′·0 and in *H* 107 γ.

On the 23rd of June a sharp decrease of force of 9 γ occurred at 17^h 26^m followed by a rapid increase of 38 γ and then a gradual return to normal in about an hour. Corresponding movements were shown on the Declination curve, but, they were less pronounced. An increase of 1′ of W. Declination and then a decrease of 3′ of W. Declination and a gradual return to normal.

On the 28th of June a moderately active disturbance was recorded from noon to midnight, the amplitude in *D* being 19′·8 and in *B* 97 γ.

From the 12th to 15th of July a light active disturbance, with an amplitude of 19′·6 in *D* and 70 γ in *H* was recorded.

On the 25th of July a moderate disturbance began at 0^h 41^m in *D* and continued until noon with an amplitude of 21′·5. In *H* it began at 16^h of the 24th and continued until 21^h of the 25th, the amplitude in *H* being 60 γ.

In June 17 days were classified as normal and in July 21.

The accompanying table gives an abstract of the magnetic results at Agincourt for June and July, 1913.

Declination

Month	Mean of Month	Max.	Date	Min.	Date	Monthly Range	Amplitudes—Mean Daily From hourly readings	From Means of Extremes
1913	° ′	° ′		° ′		° ′	′	′
June	6 18·3	6 29·5	1	5 50·5	1	0 39·0	12·4	15·1
July	6 18·8	6 31·5	20	6 03·5	21	0 28 0	10·8	14·0

Horizontal Force—C.G.S. Units

1913								
June	0·16139	0·16201	1	0·16094	1	0·00107	0·00036	0·00054
July	0·16134	0·16173	20	0·16088	30	0·00085	0·00035	0·00050

Inclination

Month	Mean Earth Inductor
1913	° ′
June	74 39·9
July	74 40·5

ASTRONOMICAL NOTES

EXTENT AND MASS OF THE UNIVERSE.—The June number of the *Observatory*, contains an interesting summary of a course of advanced astronomical lectures by R. T. A. Innes, the well-known and erudite director of the Union Observatory, at Johannesburg, South Africa ; dealing in part with the question of the extent and mass of the universe, Mr Innes, views would seem to be, in a measure at least, a distinct contribution to the philosophy of cosmology. Mr. Innes concludes that the stellar system, of which the sun is a member, and the Milky Way the girdle, is distinctly limited, and that our telescopes penetrate far into space beyond its boundaries : they do not, however. reveal any external, more distant objects—in particular, no similarly constituted stellar systems such as the spiral nebulæ have been suggested to be. The Magellanic clouds are two separated portions of the Milky Way, to which latter the star-clusters and nebulæ are intimately related. The number of stars, he considers, is limited, falling far short of the number of people on the earth ; as regards sizes, they are well mixed, small stars occurring where there are large ones, and large stars being found where small ones are numerous. The distances of the helium stars (which are further away than those of other types, and are peculiar to the Milky Way), he assigns as about 540 light-years. He dismisses the idea that there is any serious absorption of light in space ; at the worst it does not amount to 0·2 magnitude for the most distant stars, and it is, in any case, far less than the absorption of light in its passage through a few miles of our

atmosphere. Again it is very doubtful whether only one part in 200,000,000 of the sun's radiant energy is used. The sun and stars may radiate into empty space, but it is unproved, and perhaps unprovable. The existence of dark suns, similarly, is quite without demonstration at present, not one being certainly known.

Though there is some uncertainty, he makes the following rough estimate of the mass of the universe, the unit being the sun's mass :—

300	stars	100	times	the sun's	mass	= 30,000
5,000	"	10	"	"	"	= 50,000
200,000	"	1	"	"	"	= 200,000
1,000,000	"	1/10	of	"	"	= 100,000
5,000,000	"	1/100	of	"	"	= 50,000
10,000,000	"	1/1000	of	"	"	= 10,000
Small stars in clusters						= 1,000
					Total.	441,000

Thus the mass of the universe is of the order of that of half a million suns. If luminosity were considered, the arrangement would be altered, as it is probable that a majority of the stars have greater surface-brilliancy than the sun. Thus, as in the solar system, nearly all the mass is contained in a few bodies, the large majority contributing but slightly to the total. — *The Observatory*, No. 462.

Sun-Power on the Nile.—The sun-power plant which has been erected near Cairo for the purpose of carrying on irrigation work at a much cheaper rate than would be possible by the use of coal fuel, has just been inspected by Lord Kitchener. This plant for harnessing the sun's rays is the invention of Mr. Frank Shuman, an American engineer. It is hoped by this means to reclaim vast areas of desert land and bring them under cultivation. A cablegram received in London from Mr. Shuman states that the sun-power plant is doing good work with the Nile at its lowest level. Lord Kitchener, on the occasion of his visit, was much interested, and said it would be a great help in the develop-

ment of the Soudan and Upper Egypt, and he wished the promoter the best success.—*English Mechanic and World of Science*, No. 2519.

JUPITER'S SATELLITES.—The fifth satellite will perhaps be the last satellite to be discovered by direct eye observation. The success which Professor Pickering had with the photographic method in the case of the two new satellites of Saturn inspired Professor Perrine at Lick to try a similar search in the case of Jupiter. In 1905 and 1906 he discovered the sixth and seventh satellites, the orbits of which seems to coincide, moreover they intersect each other so that rather interesting dynamical questions will be proposed for solution. Two years later the eighth satellite was discovered by Mr. Melotte of Greenwich and a relatively large number of photographic measures were gathered by the Greenwich observers owing to an ingenious method of extrapolation from previous observations by which the approximate place of VIII was known in advance. This satellite takes almost two years to complete its circuit about Jupiter; its orbit is marked by an unusually large eccentricity and a likewise large inclination to the planet's orbital plane; as in the case of Phoebe its motion is retrograde. At the time of apojovium the satellite will not be very far away from the sphere of activity of the planet so that the question has been raised whether or not VIII will always continue to be a satellite of Jupiter. The shift of the line of nodes of the orbit on that of its primary is about 3° a year and the line of apsides will show a similar change. Inclination and longitude of node will reveal a behavior similar to that which the corresponding quantities of Japetus have shown, and Laplace's explanation of the disturbing influence of the sun will be directly applicable. Accurate measurements of the elongations of VIII will in the future lead to the best determination of the mass of Jupiter.—KURT LAVES, *in Popular Astronomy*, No. 6.

BEFORE COPERNICUS.—Some fifty or sixty years ago the burning questions among the historians of Greek astronomy

were the interpretation of the curious planetary system of Philolaus, and whether Plato taught the rotation of the earth and in his old age was rather inclined to place the sun in the middle of the world. These questions (fully discussed by Sir Thomas Heath) have long ago been finally settled, and have been succeeded by two others; first, how much did Greek astronomers owe to the Babylonians, and, secondly, how did the idea of the heliocentric system arise, and what connection was there between it and the development of the excentric and epicyclic system?

Greek philosophy and mathematics were developed quite independently of any Oriental influence, but as regards astronomical observations the Greeks certainly started many centuries behind their Eastern neighbours. It is therefore not to be wondered at that precession was not discovered before Hipparchus' time. All the same, the fact that the sphere of the fixed stars in the system of Philolaus had a very slow motion has, by some, been supposed to show that the Pythagoreans were acquainted with precession. The question is therefore again: Did the Babylonians know anything of precession in the fifth century B.C.? The answer seems to be that, the more we learn about Babylonian astronomy, the more certain it becomes that the Babylonians never attained that knowledge before the time of Hipparchus*. Kugler has even shown that they had no knowledge of it at the end of the second century B.C. And yet we know that by that time they had progressed far in some directions, notably as regards the motion of the moon, though they never set up a mathematical theory of it, but worked solely by cycles. Therefore the Pythagoreans, in whose system the daily rotation of the starry heavens was explained by the motion of the earth round the central fire, can only have assumed a very slow motion of it, because everything else was in motion and it would not suit their preconceived notions to let the celestial sphere form an exception. At a time when so little was known

*The same result appears from a Neo-Babylonian astronomical treatise lately published, on which Mr. L. W. King lectured before the Society of Biblical Archæology in February last.

of the motions of the planets that a system of the world could be designed which ignored the stations and retrogradations of the planets, a postalate of that kind cannot have surprised anybody. How little practical astronomy was cultivated, even in the first half of the fourth century, may be seen from the fact that the ingenious system of homocentric spheres of Eudoxus was unsatisfactory in the case of Venus, and broke down completely when dealing with the motion of Mars. Evidently Eudoxus had no exact knowledge of the length of the retrograde arc of Mars, and did not know that Venus takes three times as long to go from the greatest western to the greatest eastern elongation as it takes to go from the eastern to the western.—J. L. E. Dreyer, *in The Observatory*, No. 463.

Cumulus Cloud Disturbances.—Everyone who has carefully watched clouds is familiar with the peculiar boiling and tumbling of large cumulus clouds, their formation of new heads, and the other evidences they often give of violent motions and an explosive-like turbulence. The late Dr. W. von Bezold suggested that these movements indicate that there is a source of power within the cloud itself, and he ascribed this power to the latent heat set free by the more or less sudden condensation of a supersaturated vapour, or the sudden freezing of undercooled water-drops.

Professor W. J. Humphreys has recently investigated this subject, and he has come to the conclusion that the difference in temperature between the free air and the interior of large cumulus clouds at the same level is the real cause of the violent uprush and turmoil in their centres. He is also of opinion that most of the electrical and other energy of the thunderstorm comes directly or indirectly from the latent heat of condensation set free within the mass of turbulent cumulus clouds. — W. Marriott, *in Knowledge*, No. 539.

Lord Kelvin.—His name will pass down the ages as the out-standing guiding spirit of the period when the weapons of physical science were brought out of her secluded armoury, and

turned to the reconstruction of our material civilization. For we have now passed on rapidly from the age of steam into the age of electricity; we have had the good fortune to watch in our own day the progress of that subtle agency of silent power, until it has transformed most of the departments of industrial and social life. The dreams which were mixed with the wonder of the early electric discoverers have been more than accomplished. But this advance has become possible only by being the most conspicuous example of ordered and persistent scientific method that the world has seen. Every minute natural manifestation of electric agency, whether detected by the foresight of men like Faraday, or revealed in part by accident, has had to be accurately and closely analysed, as a prelude to eliciting its possibilities on an industrial scale. The method of true progess must have been impressed especially upon Lord Kelvin during those strenuous telegraphic years, when he was by force of circumstances dragged out of his study to battle with practical engineering difficulties—when, by submitting every phenomenon to that refined measurement and calculation which alone can lead to long secure trains of prediction and adaptation, he transformed the problems of submarine telegraphy from a blind, impracticable tangle into an ordered science. That achievement proved to be the crucial step in preparation for the present age of electricity. His disinterested persistence, through many subsequent years, in the same self-appointed task of rational measurement of electrical quantities and their relations, with the aid of the colleagues whom his zeal enticed into the service, formed the preparation, in all essentials, for uninterrupted progress as soon as opportunity came in the world of affairs for the larger industrial electric developments to be pushed on. When these immense engineering advances were in full evolution, he was growing old, but his eager foresight still dominated the practical field.

Only in one respect did he fall short, in the theoretical electric advance, when he arrested his fruitful trains of inference on the interconnections of these partially concealed agencies, in order to search strenuously during long years for their complete

elucidation, in some form such as could be exhibited and probed in a mechanical working model. Through this partial lapse of faith, this logical reluctance to take risks in following up the incomplete clues offered by nature, it fell to the most illustrious of his pupils and disciples, Clerk Maxwell, with greater daring and temporary disregard of difficulties, yet ever stimulated and guided by his master's own most instructive and inspiring though halting efforts, to connect light and heat in close linkage with electricity and magnetism, and so embrace all branches of physical science in one compact synthesis. This has been the great fundamental achievement in physical science of our age, probably the greatest since Newton announced and developed the law of gravitation. With the eye of faith, waves precisely the same in kind as those of light, only vastly magnified in size, had thus already been familar to the initiated for twenty years, with fully mental vision of their constitution and behaviour, flashing across space in electric pulses, when at length, by an accident such as comes only to the worthy, the crowning honour of first detecting their actual bodily existence was grasped by Hertz. Then, as is usual in such cases, once a practical start has been gained—the more recent advance in the practice of artifical flight is another example—development was pushed rapidly on in many hands, by theory and experiment working together, until phenomena that it had taken a quarter of a century for eager expert searchers to detect at all, have now become, in the form of wireless telegraphic signals, almost a commonplace of everyday life.—Sir J. Larmor, (Belfast Memorial) *Nature*. No. 2278, Vol. 91.

Parallax of the Andromeda Nebula.—*Astr. Nachr.* No. 4650 contains a determination of the parallax of one of the small companion nebulæ of the great one, made by M. Gustaf Strömburg at Stockholm. He obtains for the parallax 0″·073 with a probable error of 0″·055. Some previous determinations had given 0″·171, 0″·132, and 0″·070 for the parallax. As the nebula is a difficult object for precise measurement it can only be claimed that the results give some slight probability to the conclusion that it has a sensible parallax, which of course if proved would negative the idea of its being an external universe.—A. C. D. Crommelin, *in Knowledge*, No. 540. J. R. C.

NOTES AND QUERIES

Communications are Invited, Especially from Amateurs. The Editor will try to Secure Answers to Queries.

OBSERVATION OF THE SHADOW OF A SATELLITE OF JUPITER

In the last number of the JOURNAL the question was asked, if the shadow on Jupiter's disc caused by one of its satellites could be seen with a three-inch telescope, and Chief Astronomer King answered that he thought it possible, though near the limit of such an instrument.

Mr. T. H. Wingham, of Hamilton, who uses a three-inch instrument, reports that on the night of Sunday, June 29, he observed such a shadow quite plainly. He continues, "At first I thought I could see two spots, but one must have been an irregularity in the belt as it did not cross the disc as the other spot did. I watched until the shadow left the disc about 11.30 p.m. Could the HANDBOOK give us notice when we might expect to observe this interesting phenomenon?"

In regard to this question asked in the last sentence, I would say that the HANDBOOK is prepared for the use of the amateur, and if there is a general demand that such phenomena of Jupiter's satellites be included, they should be added. I shall look into the matter further and, if possible, will add them to the monthly phenomena.

METEORS IN THE BERMUDAS

As was noticed in the last JOURNAL, the great meteoric display of February 9 was well observed in the Bermuda Islands, one of the most interesting reports received being that of Col. W. R. Winter, of Paget East. Writing under date July 14, Col. Winter gives further observations of meteors. He says: "On July 5 at 7.30 p.m. a fine meteor with a radiant about equidistant between Antares and Jupiter traversed the sky in the direction of Ursa Major, bursting into three pieces after being visible on a

course of about 45°. Nucleus, about size of two diameters of Jupiter. Trail brilliant, about 7½°. Color, white with a decided green tinge. After bursting it disappeared behind a cloud. Practically no illumination of the earth. A single report followed in 5^m 42^s.

On July 11 at 8.35 p.m. a very large and brilliant meteor, with radiant point near head of Draco, traversed the sky to the S.E., bursting into four pieces E. of Aquila. The largest piece out-distanced the other three and all disappeared behind a cloud. In spite of the moonlight the earth was most brilliantly lighted up. Most people said the nucleus was as large as the moon. I considered it about half the diameter. A brilliant tail of about 10°, yellow and of greenish color. In 8^m 48 a rumble followed like thunder and finished with three quick, sharp reports, about as loud as a fowling piece at 200 yards, quite different from the one in June 1912, which was like a large gun and shook the windows.

At 10.05 p.m. on the 12th, two fair-sized shooting stars started from the same point between Jupiter and Antares, in exactly opposite directions in a perfect alignment ; one went S.S.E., the other N.N.W. I have never seen this before, have you ?"

If anyone has ever seen such a phenomenon as last described I would be glad to hear from him.

HONORS FOR CANADIAN ASTRONOMERS

It is gratifying to see the work of Canadian Astronomers recognised abroad, and I have much pleasure in giving the following brief account of the recent conferring of the degree of Doctor of Science on Messrs. Klotz and Plaskett, of the Dominion Observatory, Ottawa, the former being honored by the University of Michigan, the latter by the University of Pittsburg.

OTTO JULIUS KLOTZ.

The candidate for the degree was presented to President Harry B. Hutchins of the University by Professor C. S. Dennison. The President then read the following sketch of the candi-

date's attainments, while both stood in their places on the commencement platform.

Otto Julius Klotz, of Ottawa, Canada, a graduate of the University of Michigan, Department of Engineering in the class of 1872. Distinguished especially for his researches in magnetics, gravity and seismology, and for his work in connection with the Alaska boundary survey and the first astronomic longitude girdle around the world. At present astronomer for the Dominion Government.

JOHN STANLEY PLASKETT.

The commencement exercises of the University of Pittsburgh, were held in the beautiful Memorial Hall, near the University. There is an unwritten law in this University, not to confer more than one honorary degree of a kind at its annual commencements and Mr. Plaskett, who is a B.A. of the University of Toronto, was the unanimous choice of the Trustees this year to receive the Doctorate of Science.

Dr. John A. Brashear, a former Chancellor of the University of Pittsburgh, presented Mr. Plaskett for the degree to Chancellor McCormick, recounting some of his splendid work in the domain of astronomical physics. In closing Dr. Brashear remarked that he could pay Mr. Plaskett no higher compliment than to say that he and his American colleagues called him the "Keeler of Canada." The degree was then conferred in fitting words by the Chancellor and he was invested with the hood typical of the doctorate by Dr. S. B. Linhart, assistant to the Chancellor.

APPOINTMENT TO THE DOMINION OBSERVATORY

Dr. Reynold K. Young, has been appointed to the Dominion Astronomical Observatory, beginning his duties on August 1. Dr. Young graduated with the B.A. degree from the University of Toronto, in June, 1909, winning the R.A.S.C. gold medal. He then was appointed Fellow in the Lick Observatory and after spending three years there obtained the Ph.D. degree in 1912. During the last year he has been Instructor in Astronomy and Physics in the University of Kansas, and though promoted to be assistant professor he decided to return to Ontario. Dr. Young's home is at Binbrook, near Hamilton, and his wife is the daughter of Prof. R. G. Aitken, of the Lick Observatory. She is a graduate of the University of California with honors in astronomy.

C. A. C.